INSTRUCTION BOOK

for the

MODEL 302C

BATTERY OPERATED ELECTRONIC VOLTMETER

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY

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Printed in U.S.A

4-65-Y-03

WARRANTY

Each Ballantine Laboratories, Inc. instrument, or part thereof, is warranted to be free from defects in material and workmanship. Ballantine Laboratories, Inc. obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except vacuum tubes and batteries, which shall within one year after shipment to the original purchaser prove upon Ballantine Laboratories, Inc. examination to have become defective.

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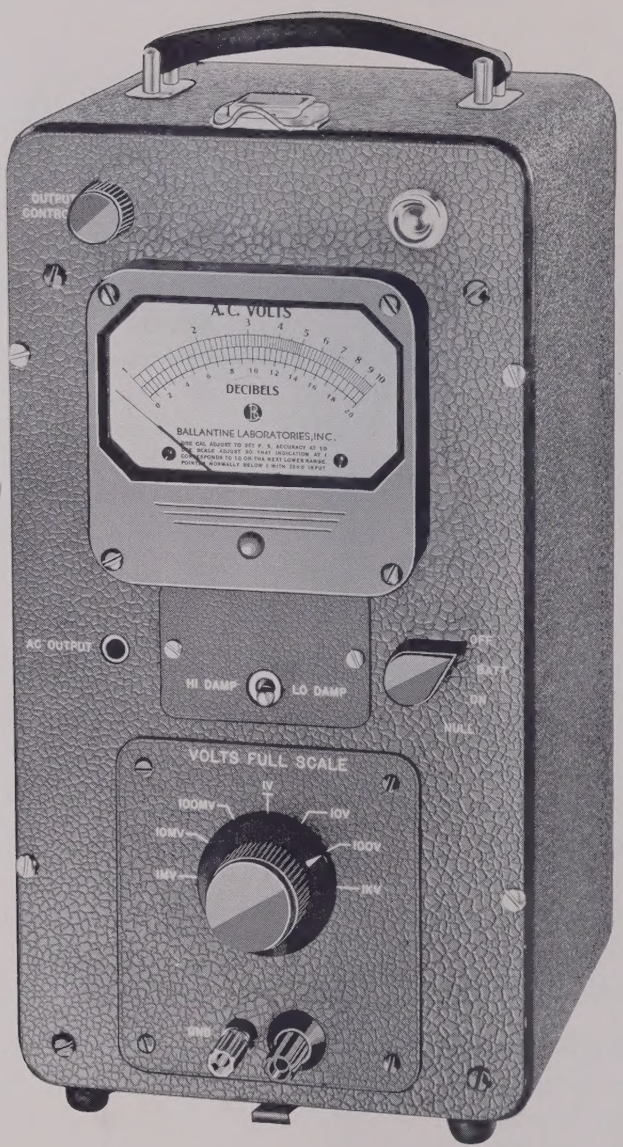

Ballantine Model 302-C
Battery Operated Electronic Voltmeter

1. SPECIFICATIONS

BALLANTINE MODEL 302C ELECTRONIC VOLTMETER

Voltage Range

100 microvolts to 1000 volts in 7 decade ranges.

Frequency Range

2 - 150,000 cps.

Accuracy

3% except 5% below 5 cps, above 100,000 cps, and above 100 volts. Accuracy figures apply to any point on meter scale.

Input Impedance

Range Switch Setting	*Input Impedance*
1 mV and 10 mV	2 megohms shunted by 25 pF
100 mV, 1 V, 10 V, 100 V, 1 kV	2 megohms shunted by 12 pF

Meter Scales

Logarithmic voltage scale reading from 1 to 10, Auxiliary scale in decibels from 0 to 20.

Output Characteristics

Maximum Output Voltage	1 volt
Source Impedance	3000 ohms max
Voltage Gain	60 db ± 0.2 db
Gain Adjustments —	
Range Switch	20 db steps
Output Control	Continuous
Frequency Response	
(2 - 150,000 cps., 100 pF loading)	
Output Control fully clockwise	±0.5 db
All other positions of Output Control	±1.0 db

Tubes

Five Type 1U4, one 1R5

Batteries

Four Eveready Type 467, four Burgess Type 2F, or Eveready Type W-353. Battery life 100 hours or more in normal use.

Pilot Lamp

Flashing neon, Type NE-51

Dimensions

6⅞ inches wide, 7½ inches high, 12⅜ inches long.

Weight

15 pounds, including batteries.

Shipping Weight

Portable: 20 pounds.

Rack: 28 pounds.

2. GENERAL DESCRIPTION AND APPLICATIONS

The Ballantine Model 302C Battery Operated Electronic Voltmeter is an amplifier-rectifier type instrument designed to measure sinusoidal voltages from 100 microvolts to 1000 volts over a frequency range from 2 to 150,000 cps. By means of a seven decade range switch, this entire voltage range is indicated on a single logarithmic voltage scale reading from 1 to 10. The accuracy of this logarithmic voltage scale is the same at any point on the scale. The indicating meter also has a linear decibel scale, numbered from 0 to 20 db, the zero of which is arbitrarily arranged for maximum usefulness so as to correspond to 1 on the voltage scale.

The fact that this voltmeter is powered by its own batteries makes it particularly useful in cases where no external AC power source is available, or where it is not desirable to use AC power because of limitations imposed by grounds or by even a small amount of residual 60 cps hum.

Essentially the Model 302C consists of a high impedance input attenuator followed by two 3-stage feedback amplifiers. Part of the range switch attenuator is placed between the two amplifiers to reduce the effects of tube noise and microphonics to a minimum. For voltage measurements the second of the two amplifiers incorporates a full wave germanium diode rectifier circuit and a logarithmic meter in its feedback loop, thereby improving the linearity of the rectifier action. The meter itself responds to the average value of the input voltage, but is calibrated to read the RMS value of a sinusoidal input. Each of the amplifiers has sufficient feedback to render the indications of the instrument substantially independent of changes in battery voltages, tubes and other components.

Inserting a standard tip and sleeve telephone plug into the AC OUTPUT jack automatically disconnects the indicating meter and makes the amplifier section of the voltmeter usable as a stable high gain pre-amplifier completely free of AC hum.

Some applications for which the Model 302C is especially suited are —

a. General voltage measurements in both grounded and ungrounded circuits, independent of AC power sources.

b. Current measurements in combination with precision shunt resistors.

c. Pre-amplification of extremely small voltages, with high input impedance and complete absence of AC hum.

3. OPERATION

3.1 Battery Test

Turn the function switch, located on the right-hand side of the front panel, from OFF position to BATT. A reading on the meter scale of 8 or above indicates satisfactory battery voltage. If the reading is less than 8 all the batteries should be replaced, as outlined in Section 4.1.

3.2 Range Selection

Turn the range switch to the proper decade for the voltage to be measured. The position of the range switch indicates the voltage input necessary for full-scale deflection of the indicating meter. If the approximate magnitude of the voltage is unknown, rotate the range switch fully clockwise to the 1 kV position before connecting the signal to the input terminals. This procedure will provide the maximum protection in case of overload.

3.2.1 Decibel Scale — The zero of the decibel scale is arbitrarily arranged for maximum usefulness so as to correspond to 1 on the voltage scale. Table I gives the values to be added or subtracted to this decibel scale to relate the reading to any of the four common reference levels.

TABLE 1

Range	1 mW in 1000 ohms (dbv)	1 mW in 600 ohms (dbm)	6 mW in 500 ohms	6 mW in 600 ohms
1 mV	—80 db	—77.8 db	—84.8 db	—85.6 db
10 mV	—60	—57.8	—64.8	—65.6
100 mV	—40	—37.8	—44.8	—45.6
1 V	—20	—17.8	—24.8	—25.6
10 V	0	2.2	— 4.8	— 5.6
100 V	20	22.2	15.2	14.4
1 kV	40	42.2	35.2	34.4

3.2.2 Input Impedance — The impedance across the input terminals is a function of the range switch position. On the 1 mV and 10 mV positions, the input impedance consists of a shunt component of resistance of 2 megohms in parallel with 25 pF. On all other ranges the impedance is 2 megohms and 12 pF. Should it be desired to measure the input impedance accurately, a resonance method employing impedance substitution is recommended. The instrument should be on, and care should be taken not to exceed the full-scale voltage for the range being measured.

3.2.3 Noise Level — The equivalent noise level referred to a low source impedance is normally less than 10 microvolts, and consists of random thermal and flicker noises. The signal-to-noise ratio for on-scale readings on the 1 mV, 100 mV and 10 V ranges is better than 20 db, and for all other ranges is more than 40 db.

3.3 Voltage Measurements

Connect the signal to the input terminals. The terminal marked GND is connected to the instrument case. Therefore, measurements made at points above ground (either AC or DC) should be made only with proper precautions to the shock hazard and instrument loading effects incurred.

Turn the function switch to ON. Because of the large capacitors employed to achieve the low-frequency response, about 20 seconds is required after first turning on the voltmeter to enable it to reach a condition of equilibrium. This will be indicated by the meter pointer assuming a stationary position after drifting over the scale for a short time.

3.3.1 For Frequencies Below 10 cps — If the signal being measured is at a frequency below 10 cps, the toggle switch just above the range switch should be turned to the HI DAMP position. This connects a

large capacitor across the meter, which increases the meter damping and reduces the flutter of the meter pointer. This switch should always be returned to the LO DAMP position except when pointer flutter is excessive because, while the added damping does not affect the accuracy of the readings, the meter requires more time to respond to a change in signal voltage.

3.3.2 Effect of Wave Form — The indications of this voltmeter are proportional to the average value of the AC signal. Since, however, it is primarily intended to measure sinusoidal waves the voltmeter is calibrated in terms of the RMS value of a sine wave. Electronic voltmeters of the diode-rectifier type respond to the peak value of the wave. Therefore the readings of such meters and the Model 302C will not necessarily agree when harmonics are present.

The amount of the discrepancy will depend on the number and magnitude of the harmonics present, as well as the frequency of the fundamental and the phase relationships of the harmonics to the fundamental. In most cases, however, the departure of the readings from true RMS values due to the presence of harmonics will be less with an average responding meter, such as the Model 302C, than with a peak responding meter. Table II compares the errors of the two types of voltmeters to the RMS indication of waves with various harmonics whose amplitude is 20% of the fundamental and whose phasing is such as to produce the maximum error.

TABLE II

Form of Wave	RMS Value of Fundamental Plus Harmonic	Maximum Error Peak Responding Meter	Maximum Error Average Responding Meter
Pure Sine	1	0	0
Sine Plus 20% 2nd Harmonic	1.02	20%	1.9%
Sine Plus 20% 3rd Harmonic	1.02	20%	6.7%
Sine Plus 20% 4th Harmonic	1.02	20%	1.7%
Sine Plus 20% 5th Harmonic	1.02	20%	4.0%

Furthermore, since the Model 302C responds to the average value of the AC wave, turn-over discrepancies occasioned by any lack of symmetry of the wave, such as are experienced in half-wave peak reading instruments, are eliminated.

3.3.3 For Voltages Below 100 μV — Voltages below 100 μV in the frequency range from 10 to 150,000 cps may be measured directly with the Model 302C by using it in conjunction with the Ballantine Model 220C Decade Amplifier. For signals with less than 500 ohms source impedance, voltages as low as 20 μV may be measured with accuracies of better than 10%. Voltages as low as 20 μV may be measured with accuracies in the order of 20% by use of the NULL position of the function switch. Although designed for use with AC bridges, as described in Section 3.6, the NULL position can be used for voltage measurement by noting the difference in meter scale readings, with the function switch set to NULL, for the range switch in the 1 mV and 1 V position. This difference times 100 is the magnitude of the signal voltage in microvolts.

3.3.4 For Voltages Above 1 kV — Voltages from 1 V to 10 kV may be measured with a loading impedance of approximately 40 megohms shunted by 3 pF by using a Ballantine Model 1310B Multiplier with the Model 302C.

3.4 Current Measurements

By using Ballantine Series 600 Precision Shunt Resistors in conjunction with this voltmeter, currents from 0.1 microampere to 3 amperes may be measured over the entire frequency range of the Model 302C with an accuracy approaching that of the voltmeter. The lowest shunt available for minimizing voltage drops is 0.01 ohm, which may be used to measure currents from 10 milliamperes to 10 amperes up to 20,000 cps. with an added error of less than 1%.

3.5 Use As Amplifier

Inserting a standard tip and sleeve telephone plug into the AC OUTPUT jack disconnects the meter and makes the amplifier section usable as a stable high gain pre-amplifier free of AC hum. With the range switch set to 1 mV and the OUTPUT CONTROL in its maximum clockwise position, the gain of the amplifier is 60 db $\pm$ 0.2 db. This may be reduced to either 40 or 20 db by setting the range switch to the 10 mV or 100 mV positions respectively, or to any intermediate position by means of the OUTPUT CONTROL. The maximum undistorted output voltage is 1 volt, with an output resistance of approximately 2700 ohms. For a capacitive load of about 100 pF, and with the OUTPUT CONTROL in its maximum clockwise position the amplifier will give a response uniform within $\pm$ 0.5 db over the entire frequency range from 2 to 150,000 cps.

3.6 Use As Null Indicator

By turning the function switch fully clockwise to NULL a small bias current is supplied to the meter which brings the pointer to an On-Scale reading even in the absence of a signal input. The voltmeter is now no longer a direct-reading instrument, but can be used on the 1 mV range to indicate relative magnitudes of potentials, such as AC bridge unbalance voltages, from 100 microvolts to below 20 microvolts.

3.7 Overload Characteristics

The amplifier circuits are designed to saturate promptly when the voltage exceeds the full-scale indication of the meter, thus protecting the meter movement. The maximum AC signal voltage overload which may be applied to the instrument is determined by damage likely to occur to the input attenuator and the first amplifier tube. Table III shows the maximum RMS voltage that can be applied continuously to the input terminals without damage to the instrument.

TABLE III	
Range	*Max. RMS Input*
1 mV, 10 mV	1 V
100 mV, 1 V	100 V
10 V, 100 V, 1 kV	1 kV

Any DC component of the signal is removed at the input terminals by a capacitor of 600 volts rating. For peak values of AC signals plus DC voltages exceeding 600 volts, an external blocking capacitor must be used.

3.8 Scale Adjustment

Scale adjustment is made by removing the small escutcheon plate covering the meter damping switch and exposing the panel control marked SCALE ADJ. Its function is to bring the 10 on one range to exactly 1 on the next higher range. Ordinarily no adjustment should be necessary other than for ambient temperatures above 30°C. where the efficiency of the meter rectifiers diminishes slightly.

If some discrepancy is noted, connect a stable source of pure sinusoidal AC at any convenient frequency from 50 to 1,000 cps. This source should have an output impedance of less than 50,000 ohms. Adjust so that the meter reads 10 on the scale. Switch to the next higher range. The meter should read 1. If it does not, the SCALE ADJ control should be adjusted until the meter does read 1. Switch back to the lower range to check that the meter still reads 10. If not, readjust the input voltage and repeat the scale adjustment. In the past some users have misunderstood the purpose of the scale adjustment and have tried to use it to bring the meter pointer to 1 on the scale with no voltage applied to the input terminals. The indicating meter, being logarithmic, has no zero. The normal position of the pointer with no input voltage applied is against the left-hand stop and off scale. Unless the function switch is in the NULL position, see Sections 3.3.3 and 3.6, the meter should indicate a reading of 1 or more only when a voltage within the range of the instrument is applied to the input terminals.

3.9 Calibration Adjustment

Normally no attention need be given to the matter of calibration as the large amount of feedback in the instrument gives it sufficient inherent stability to maintain the original factory calibration within the accuracy specified. However, to correct errors which might result from the cumulative effects of tube aging or wide variations in characteristics of replacement tubes from average tubes, a variable control has been provided which allows the calibration to be shifted a small amount. This control is also located under the small panel escutcheon plate and is marked CAL ADJ. In adjusting the calibration, the source should be a pure sinusoidal wave of any convenient frequency from 50 to 1,000 cps., and the RMS indicating voltmeter used as a standard should be accurate to at least 1%, preferably to 0.5%.

4. SERVICE AND MAINTENANCE

4.1 Battery Replacement

The batteries are indicated on the attached circuit drawing as A_{12}, A_{34}, A_{56}, A_{78}, B_1 and B_2. If the voltmeter is to read within the limits of its specified accuracy, the voltages of the various batteries, as measured with a voltmeter of 1000 ohms per volt and with the Model 302C turned on, should not be less than the following —

A_{12}, A_{56} — 1.2 volts each
A_{34}, A_{78} — 1.3 volts each
B_1 — 115 volts
B_2 — 112 volts

If all batteries are fresh when installed, B_2 will be the first to reach the minimum permissible voltage. Therefore, in order to simplify the testing of the condition of the batteries, provision is made for measuring the voltage of B_2 on the indicating meter when the function switch is turned to BATT. As explained in Section 3.1, a reading of less than 8 for the battery test indicates an insufficient B_2 voltage. Since, however, the other batteries will only operate for a relatively short time before they, too, will fall below their minimum permissible voltages, all the batteries should be replaced if the meter reads less than 8.

The batteries are accessible when the panel is removed from the outer case by loosening the four nickel-plated screws on the face of the panel. The battery replacements should be installed as shown on the attached battery placement drawing. The plugs terminating the battery cable assure proper polarity connection. It is recommended that the batteries be removed from the case as soon as they become exhausted, since otherwise they may swell and become difficult to remove.

4.2 Tube Replacement

The tube complement consists of five Type 1U4 and one Type 1R5. If trouble develops, and the condition of the batteries and battery connectors is satisfactory, the tubes should be checked. The three tubes on the right side of the chassis (viewed from the panel exterior) should be reasonably free from noise and microphonic effects, as may be determined by headphones plugged into the AC OUTPUT.

If the trouble is not remedied by these changes, the instrument should be returned to us for servicing.

4.3 Pilot Lamp Replacement

The Model 302C is fitted with a neon pilot lamp operated in a relaxation oscillator circuit. This causes negligible battery drain. Access to the neon lamp, NE51, is achieved through the front panel by unscrewing the plastic jewel in the lamp housing.

5. SHIPPING INSTRUCTIONS

If the instrument is returned to Ballantine Laboratories for servicing, make certain that at least 4 inches of padding material surrounds the instrument. Ship via Railway Express, and send under separate cover a full description of the trouble.

REPLACEMENT PARTS LIST

REFER TO MODEL 302C SCHEMATIC DIAGRAM, ISSUE MC675H

B. L. Part No.	*Circuit Symbol*	*Capacitors*	*Manufacturer*
2356	C1	.22 μF, Type 620M, 600 V, 10%	Goodall
2429	C2	7-45 pF, Type TS2A-N500	Erie
2232	C3	150 pF, Type CM-15-E-151-J	Arco
2247	C4	.02 μF, Type C-1A3S2	Cornell-Dubilier
2436	C5	.6-2 pF, Type 160205	Johnson
2244	C6	5 pF, Type CM-15-C-050K	Arco
2014	C7A	50 μF, Type DFP, 150 V	Sprague
2014	C7B	50 μF, Type DFP, 150 V	Sprague
2351	C8	1 μF, Type 621M, 200 V, 10%	Goodall
2063	C9	3000 μF, Type BRHEX, 3 V	Cornell-Dubilier
2016	C10	100 μF, Type DFP, 150 V	Sprague
2355	C11	.022 μF, Type 621M, 200 V, 10%	Goodall
2376	C12	.15 μF, Type 355C154K, 200 V, 10%	Gudeman
2077	C13	8 μF, Type BBR8-150, 150 V	Cornell-Dubilier
2244	C14	5 pF, Type CM-15-C-050-K	Arco
2451	C15	1-8 pF, Type 532-10	Erie
2222	C16	10 pF, Type CM-15-C-100-J	Arco
2226	C17	3 pF, Type CM-15-C-030-M	Arco
2352	C18	.47 μF, Type 621M, 200 V, 10%	Goodall
2352	C19	.47 μF, Type 621M, 200 V, 10%	Goodall
2404	C20	1600 pF, Type X305	Arco
2013	C21	50 μF, Type DFP, 150 V	Sprague
2351	C22	1 μF, Type 621M, 200 V, 10%	Goodall
2353	C23	.22 μF, Type 621M, 200 V, 10%	Goodall
2036	C24	500 μF, Type DFP, 25 V	Sprague
2118	C25	.22 μF, Type 109P22402, 200 V	Sprague
2201	C26	2 pF, Type CM15-C-020-M	Arco
		Resistors	
1319	R1	20,400 ohms, Type CPX-½, 1%	Aerovox
1460	R2	2,000,000 ohms, Type CPX-1, 1%	Aerovox
1416	R3	180 ohms, Type CPX-½, 1%	Aerovox
1369	R4	20 ohms, Type CPX-½, 1%	Aerovox
1460	R5	2,000,000 ohms, Type CPX-1, 1%	Aerovox
1024	R6	150,000 ohms, Type EB, 5%	Allen-Bradley
1353	R7	140 ohms, Type CPX-½, 1%	Aerovox
1064	R8	220 ohms, Type EB, 5%	Allen-Bradley
1040	R9	20,000 ohms, Type EB, 5%	Allen-Bradley
1024	R10	ohms, Type EB, 5%	Allen-Bradley
1009	R11	1,500,000 ohms, Type EB, 5%	Allen-Bradley
1061	R12	510 ohms, Type EB, 5%	Allen-Bradley
1009	R13	1,500,000 ohms, Type EB, 5%	Allen-Bradley
1320	R14	20,000 ohms, Type EB, 5%	Allen-Bradley
1024	R15	150,000 ohms, Type EB, 5%	Allen-Bradley
1461	R16	1,000,000 ohms, Type CPX-1, 1%	Aerovox
1308	R17	111,100 ohms, Type CPX-½, 1%	Aerovox
1024	R18	150,000 ohms, Type EB, 5%	Allen-Bradley
1343	R19	470 ohms, Type CPX-½, 1%	Aerovox
1009	R20	1,500,000 ohms, Type EB, 5%	Allen-Bradley

REPLACEMENT PARTS LIST

REFER TO MODEL 302C SCHEMATIC DIAGRAM, ISSUE MC675H

B. L. Part No.	*Circuit Symbol*	*Resistors*	*Manufacturer*
1061	R21	510 ohms, Type EB, 5%	Allen-Bradley
1024	R22	150,000 ohms, Type EB, 5%	Allen-Bradley
1009	R23	1,500,000 ohms, Type EB, 5%	Allen-Bradley
1039	R24	22,000 ohms, Type EB, 5%	Allen-Bradley
1036	R25	33,000 ohms, Type EP, 5%	Allen-Bradley
1342	R26	540 ohms, Type CPX-½, 1%	Aerovox
1338	R27	1,000 ohms, Type CPX-½, 1%	Aerovox
1823	R28	1,000 ohms, Type 43-1000 Potentiometer	Clarostat
1007	R29	2,000,000 ohms, Type EP, 5%	Allen-Bradley
1916	R30	5,000,000 ohms, Type Q Potentiometer	I. R. C.
1917	R31	3,000 ohms, Type Q Potentiometer	I. R. C.
	*R32	100,000 ohms, Max., Type EB, 5%	Allen-Bradley
1324	R33	10,000 ohms, Type CPX-½, 1%	Aerovox
1324	R34	10,000 ohms, Type CPX-½, 1%	Aerovox
1005	R35	3,000,000 ohms, Type EB, 5%	Allen-Bradley
1461	R36	1,000,000 ohms, Type CPX-1, 1%	Aerovox
	*R37	10 meg, 13 meg, 18 meg, Type EB, 5%	Allen-Bradley
1005	R38	3,000,000 ohms, Type EB, 5%	Allen-Bradley
1057	R39	1,000 ohms, Type EB, 5%	Allen-Bradley
1044	R40	10,000 ohms, Type EB, 5%	Allen-Bradley
1014	R41	510,000 ohms, Type EB, 5%	Allen-Bradley

*The values of these items are determined during the calibration of the instrument and may differ from the values listed.

B. L. Part No.	*Circuit Symbol*	*Other Components*	*Manufacturer*
3090	A12, A34 A56, A78	Battery, 1.5 V each, Type W-353, or equal. Four required	Eveready
3092	B1-B2	Battery, 67.5 V each, Type 467, or equal. Two required for B1, and two required for B2	Eveready
1588	CR1	Varistor, Type 19PA1-V	I. R. C.
3144	CR2, 3	Crystal Diodes, Type S53	Transitron
3173	M1	Indicating Meter	Ballantine
3118	NE	Neon Bulb, NE-51	General Electric
1583	RT1	Thermistor 43R1, 31500 Ohms	Victory Engineering
3248	S1, 2, 3, 4	Off-BATT TEST-On-Null Switch	Ballantine
3249	S5	Range Selector Switch	Ballantine
3268	S6	Lo-Hi Damp Switch, 80994BD	Arrow-Hart & Hegeman
3111	V1, 2, 3, 4, 5	Type 1U4 Tube	G. E.
5552	V6	Type 1R5 Tube	G. E.